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ORIGINAL ARTICLE

A Specific Inpatient Aquatic Physiotherapy Program Improves Strength After Total Hip or Knee Replacement Surgery: A Randomized Controlled Trial

Ann E. Rahmann, BPhy, Sandra G. Brauer, PhD, Jennifer C. Nitz, PhD

ABSTRACT. Rahmann AE, Brauer SG, Nitz JC. A specific inpatient aquatic physiotherapy program improves strength after total hip or knee replacement surgery: a randomized controlled trial. *Arch Phys Med Rehabil* 2009;90:745-55.

Objective: To evaluate the effect of inpatient aquatic physiotherapy in addition to usual ward physiotherapy on the recovery of strength, function, and gait speed after total hip or knee replacement surgery.

Design: Pragmatic randomized controlled trial with blinded 6-month follow-up.

Setting: Acute-care private hospital.

Participants: People (n=65) undergoing primary hip or knee arthroplasty (average age, 69.6±8.2y; 30 men).

Interventions: Participants were randomly assigned to receive supplementary inpatient physiotherapy, beginning on day 4: aquatic physiotherapy, nonspecific water exercise, or additional ward physiotherapy.

Main Outcome Measures: Strength, gait speed, and functional ability at day 14.

Results: At day 14, hip abductor strength was significantly greater after aquatic physiotherapy intervention than additional ward treatment ($P=.001$) or water exercise ($P=.011$). No other outcome measures were significantly different at any time point in the trial, but relative differences favored the aquatic physiotherapy intervention at day 14. No adverse events occurred with early aquatic intervention.

Conclusions: A specific inpatient aquatic physiotherapy program has a positive effect on early recovery of hip strength after joint replacement surgery. Further studies are required to confirm these findings. Our research indicates that aquatic physiotherapy can be safely considered in this early postoperative phase.

Key Words: Arthroplasty; replacement; Hydrotherapy; Physical therapy modalities; Rehabilitation.

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DISABILITY FROM OSTEOARTHRITIS is multifactorial,^{1,2} with joint replacement surgery considered only at the end-stage of the disease process.³ Over 64,000 primary THRs and TKRs were undertaken in Australia from 2005 to 2006, an increase of 3.5% from the previous year, and of 100.5% in 12 years.⁴ Similarly, in the United States, the rates of primary joint replacement surgery in the 10 years from 1993 to 2002 increased 43% to nearly half a million procedures a year.⁵ Rising rates of joint replacement surgery have resulted in increased pressure to reduce LOS and contain costs in primary health care.⁶ In this context, it is surprising to find that while evidence exists to support functional physiotherapy exercises after discharge with a lower-limb joint replacement,⁷ inpatient physiotherapy intervention has rarely been investigated by controlled trials, and little evidence exists regarding best practice.⁸ A recent review of Australian inpatient physiotherapy services after TKR highlighted the lack of clinical trials examining this area, particularly active exercise and aquatic physiotherapy, despite these being considered treatments of choice by clinicians.⁹ Investigating physiotherapy intervention in the early postoperative phase after joint replacement surgery is therefore warranted.

Aquatic physiotherapy undertaken in a hydrotherapy pool can be an option in acute hospitals where facilities exist. Exercise in water has been advocated clinically for young, active people from day 1 after hip arthroscopy,¹⁰ but whether it is beneficial early after joint replacement surgery for degenerative osteoarthritis has not, to our knowledge, been previously investigated in an RCT. Usual postoperative physiotherapy in the ward includes a combination of exercises to prevent circulatory complications, static and active strengthening, range of motion, and gait training.^{11,12} The early days after orthopedic surgery are important for optimal recovery,¹³ and aquatic physiotherapy offers specific additional benefits in this early postoperative period compared with ward physiotherapy.¹⁰ Hydrostatic forces from immersion combined with exercise can reduce lower-limb swelling.^{14,15} Changes in the autonomic and circulatory systems when in thermo-neutral water (34.5°C) increase blood flow to muscles and tissues to aid healing, and

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List of Abbreviations

CI	confidence interval
CONSORT	Consolidated Standards of Reporting Trials
HHd	handheld dynamometer
LOS	length of stay
OA	osteoarthritis
PSFS	Patient-Specific Functional Scale
RCT	randomized controlled trial
THR	total hip replacement
TKR	total knee replacement
TUG	Timed Up & Go
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

the sensory interpretation of pain can also be modulated.¹⁶ In addition, decreased loading of joints and tissues occurs from the effect of buoyancy.¹⁷ The combination of these factors means that functional strengthening such as step-ups, squats, and the initial re-education of a normal symmetrical gait pattern without the use of walking aids can commence earlier in the water than on the ward. Functional retraining is an important focus of rehabilitation and has been shown to be beneficial after similar orthopedic procedures in both the early¹⁸ and later^{19,20} phases of rehabilitation. Whether a specific aquatic exercise program offers any additional benefit compared with either supplementary ward physiotherapy or a general water exercise program in these early days after joint replacement surgery is not known.

An important pre-existing factor that can influence postoperative recovery is the extent of muscle dysfunction from disuse and inhibition combined with aging.²¹⁻²³ Many studies have found that strength deficits persist, even after the completion of usual THR and TKR rehabilitation.²⁴⁻²⁶ Gait dysfunction can also persist for many months after joint replacement.^{27,28} Improvement in quadriceps strength has been correlated with improved gait speed in people with osteoarthritis.^{29,30} However, despite the importance of hip abductor strength in mediolateral stability and gait,^{31,32} quadriceps strength has been investigated far more frequently in people with osteoarthritis and after joint replacement surgery.³ Hip abductor strength alters with age,^{33,34} with symptomatic hip OA,^{35,36} in knee pathology,^{37,38} and after knee surgery,³⁹ and is reduced in people with recurrent ankle sprains.^{40,41} Reduced hip abductor strength may also be a factor in the ongoing gait dysfunction after joint replacement surgery but has rarely been studied. Considering the paucity of studies to date, hip abductor strength is an important aspect to consider in functional recovery after knee or hip replacement surgery. Combining the assessment of strength with gait speed and self-reported function will allow a broader understanding of early recovery after joint replacement surgery.

Thus, the research questions for this trial were the following: in persons who have had a THR or TKR, (1) does inpatient aquatic physiotherapy have a greater effect on hip abductor strength, gait speed, and function than additional ward treatment, and (2) does a specific aquatic physiotherapy program result in greater changes in strength, gait speed, and function than general water exercise?

METHODS

Design

A pragmatic, RCT was conducted with measures taken preoperatively and at day 14, day 90, and day 180 after surgery. The primary endpoint was day 14. The trial was designed and reported according to the CONSORT guidelines.

Participants

Persons having a primary hip or knee replacement for osteoarthritis were recruited from an orthopedic practice whose 2 surgeons undertake in total over 150 hip and knee replacement operations a year. If a home visit was not possible prior to admission or if they lived outside the metropolitan area, persons were not recruited. Volunteers were excluded if they reported any diagnosed neurologic disorder, had another major musculoskeletal problem that altered mobility other than the specified joint (eg, low back pain, severe OA in another lower-limb joint) or cognitive dysfunction, or were undergoing revision joint surgery or bilateral knee replacements. Those who

specifically requested aquatic physiotherapy postoperatively and were not willing to be randomized were also excluded.

Procedure

Participants were assessed preoperatively and on day 14, day 90, and day 180 after surgery. After initial assessment, participants were randomly allocated using sealed, identical envelopes that had been prepared, shuffled, and numbered consecutively prior to the commencement of the study. Exclusion criteria were applied again at day 4 prior to commencement of the intervention, and the respective surgeon confirmed each participant was medically stable and able to begin the intervention. Because of the nature of the trial, ward physiotherapists and participants could be blinded only to the type of aquatic intervention. The aquatic physiotherapists could not be blinded in order to undertake the specified treatment protocol for each subject. Physiotherapists from a domiciliary allied health service based at a different metropolitan hospital undertook all home visits for the postdischarge assessments with few exceptions and were blinded to treatment allocation. Reliability was demonstrated between all therapists for strength measurements (intraclass correlation coefficient=.87). All other objective outcomes were standard measures used by the domiciliary service and in usual clinical practice. Ethical approval was obtained from both the hospital and university medical ethics committees. Verbal consent was obtained from all volunteers by telephone prior to the initial home visit, and written informed consent was obtained prior to commencing the baseline measurements.

Intervention

All ward and aquatic physiotherapists involved in the trial had more than 5 years of experience in the treatment of postoperative orthopedic patients. No physiotherapist provided both ward and aquatic intervention. Every participant received standard ward physiotherapy as clinically determined by the treating physiotherapist for the first 3 days postoperatively. Throughout the intervention stage of the trial, all participants continued to receive 1 ward physiotherapy treatment each day, following the standard orthopedic clinical pathway used at the hospital. The experimental treatment was provided in addition to usual care. From day 4 after surgery, participants received an additional ward physiotherapy treatment each day or completed 1 of the 2 aquatic treatment programs daily until discharge. All treatments, both in the ward and in the pool, were 1-on-1 individual physiotherapy treatment sessions to standardize intervention between the groups and also to allow close monitoring of the physiologic response to immersion in the early days after surgery.

Specific details of each program are included in [appendix 1](#). Progressions were determined by the treating physiotherapists' clinical judgment and recorded in treatment notes, in accordance with usual clinical practice. The aquatic physiotherapy and water exercise components took place in the hospital-based, enclosed hydrotherapy facility, with water maintained at thermo-neutral temperature (34.5°C), at which temperature any adverse physiologic effects of immersion are minimized.¹⁶ The pool had a ramp access, and depth ranged from 1 to 1.5m, allowing participants to be immersed at the appropriate depth and progressed as described in the treatment programs. The aquatic physiotherapy program had been specifically developed to maximize function and strength in the early postoperative phase and had been routinely used for patients having joint replacement surgery prior to this trial. The water exercise program was a series of general exercises not targeted at

specific functional retraining in the aquatic environment. A metronome was used to standardize the pace of particular exercises (see [appendix 1](#)) because speed has an effect on movement in water.⁴² Once day 14 measurements had been completed, participants were free to undertake whatever, if any, postdischarge physiotherapy they chose.

Surgical wounds were covered with an occlusive, waterproof dressing, routinely used after surgery in the hospital.^a Early aquatic physiotherapy had been usual practice within this hospital for a number of years. All hydrotherapy assistants and nursing staff were familiar with preimmersion and postimmersion protocols involving checking dressings prior to immersion and changing dressings as soon as possible on return to the ward.

Measurement Tools

The disability from OA is multifactorial,²⁸ so measuring a single outcome or domain is unlikely to be sufficient to investigate postoperative recovery. Guidelines for suggested outcome measures in osteoarthritis trials recommend measures of pain, physical function, and generic measures of health status.⁴³ Because joint replacement surgery is undertaken to improve these factors, using similar measures for the immediate postoperative period is indicated. Three primary outcome measures were chosen for this study: hip abductor strength, 10-m walk time, and the WOMAC score, with the primary endpoint of interest day 14 postoperatively. Participants were followed up for 6 months after surgery to determine whether any early postoperative differences between groups persisted.

Hip abductor strength. Strength of hip abduction on the operated side was measured using an HHD.⁶ An HHD has been shown to be reliable both within sessions and over time in older people⁴⁴⁻⁴⁶ and has been used previously for follow-up after orthopedic surgery.^{47,48} Testing was undertaken supine with the tested limb in neutral rotation to standardize measurement across all periods, using a previously published protocol.^{18,49} The HHD was positioned against the lateral thigh, 30cm distal to the greater trochanter. Three repetitions of an isometric make test were performed, and the mean value of the 3 trials was used in data analysis because the mean has been shown to be more reliable in an older population.⁵⁰ Results were recorded in standard units (kg) as recommended.⁴⁴

Walking speed. Timing of preferred walking speed measures the recovery of gait velocity,⁵¹ has often been used to measure functional ability in osteoarthritis,⁵² and is useful because it relates to functional tasks such as the ability to walk quickly enough to cross a road.⁵³ The timed 10-m walk test⁵⁴ was chosen because it could be easily measured early after surgery and is a commonly used clinical outcome measure. Walking speed over 10m from a standing start at the participant's preferred pace was measured using a stopwatch.^{55,56} Because of the potential effect of pain and reduced mobility early after surgery and because of the number of outcomes to be assessed, 1 trial was performed. Mobility aids were used if required in the early postoperative period, provided no physical assistance was needed from another person.

Self-reported disability. The WOMAC Index,⁵⁷ a self-rated measure of pain, function, and stiffness, is one of the most widely used disease-specific outcome measures in joint replacement surgery research.^{58,59} The total WOMAC score assessed with the Australian Likert scale (V3 Australia LK3.1) version of the WOMAC Index was used for this trial, with each question rated on a 5-point scale: none, mild, moderate, severe, or extreme.

Secondary outcome measures. A variety of secondary outcome measures were also collected. Because quadriceps strength is frequently an outcome measure in similar trials, isometric strength of the quadriceps and also the hamstrings of

the operated side were measured with the knee at 90° and the subject sitting. An HHD was placed 20cm below the inferior pole of the patella to measure quadriceps strength and posterior to this point for hamstrings strength. The mean of 3 make tests was used in analysis. Maximum active knee flexion range was measured in sitting using a goniometer. Circumferential measurements are a reliable method, commonly used by therapists, to monitor the changes in lymphedema of the limbs.⁶⁰ Knee circumference, measured at the mid-patella level, was used in this study to examine whether immersion had any beneficial effect on swelling and was measured with a tape measure and the knee in full extension. The TUG test⁶¹ was used to measure functional mobility, with walking aids used if required.

Two subscales of the Arthritis Self-Efficacy scale, the self efficacy to achieve outcomes and the self efficacy to manage symptoms, were used to examine the effect of the different treatment protocols on the perceived confidence to manage both symptoms and function/participation.⁶² The PSFS⁶³ was used to record how quickly people returned to participate in activities that were important to them. This scale has been shown to be valid and reliable for people who have knee dysfunction.⁶⁴ Participants were asked to nominate up to 5 activities preoperatively that were difficult and that they wished to return to after their surgery. Each was then scored out of 10 with 0 being "unable to do" and 10 being "able to do at a level normal for me."

Hospital LOS and the number of additional physiotherapy interventions were recorded to determine whether the different treatment regimens affected LOS and to ensure equivalent treatment intervention in each group.

Data Analysis

Data analysis was completed on an intention-to-treat basis. The last observation was carried forward if reassessment data were incomplete, except if the missing data were at day 14, when the group average was used. This method has been widely used, including in similar studies,²⁹ and was considered a conservative way to manage missing data. After data were screened, univariate 1-way analyses of variance were used to examine differences in baseline data between groups for continuous data and the Kruskal-Wallis univariate test for categorical data. Variables that were significantly different between groups at baseline were used as covariates in further analyses. Independent *t* tests for parametric variables and Mann Whitney *U* tests for nonparametric variables were used to compare preoperative baseline measures of hip and knee replacement participants to determine whether any differences existed between the 2 groups before surgery.

Repeated-measures general linear models were used to examine the differences between the ward and aquatic groups and the aquatic and water exercise groups over time (3 intervention groups at each of the 4 periods). Means $\pm$ SDs and within-group (SE) and between-group differences (95% CIs and $P < .05$) were calculated. A clinically important difference between an intervention group and a control group has been defined in rehabilitation research as a relative difference of greater than 15% in the change from baseline.⁶⁵ To calculate this relative difference, the mean within-group change from baseline of the control group is subtracted from the mean within-group change from baseline of the intervention group. This value is then divided by the mean of the baseline measures of the 2 groups and converted to a percentage. Because of small subject numbers, subgroup analysis by surgery type within intervention groups was only undertaken to determine whether there were any differences in the 3 primary outcome measures and the 2 secondary strength measures to provide guidance for further research.

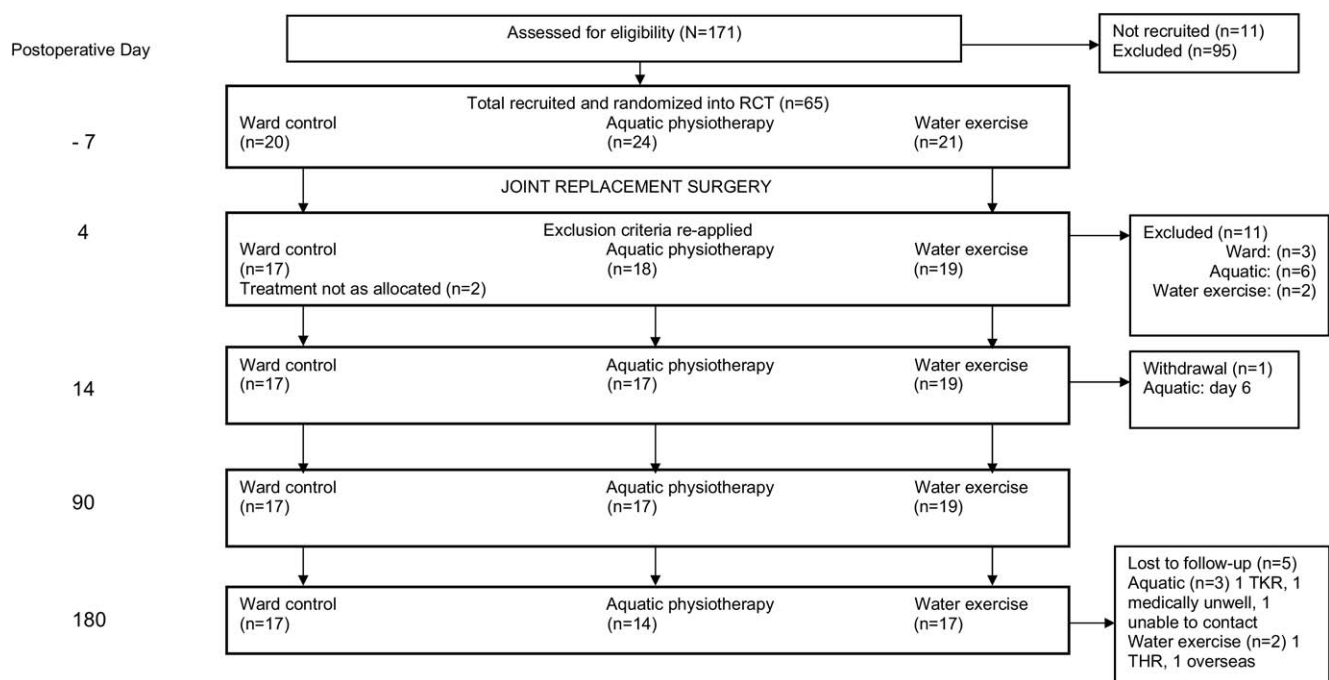


Fig 1. Flow of participants through the trial.

Data analysis was performed using SPSS for Windows.^c Alpha level was set at P less than .05 for the primary outcomes. A Bonferroni correction was used as a conservative method of adjusting the significance in view of the multiple comparisons undertaken. The alpha level of .05 was divided by 8, 1 less than the total number of outcome measures, and this gave an alpha level of P equal to .006 to use for secondary outcomes.

The sample size calculation was based on pilot data, using an alpha level of .05 and 80% power. To detect a significant difference ($P < .05$) in abductor strength between the aquatic and ward treatment groups, 16 participants a group were required, giving a sample size of 48. To allow for postoperative complications, the trial aimed to recruit 66 participants with 22 in each of the treatment groups.

RESULTS

Flow of Participants Through the Trial

Between September 2003 and September 2005, 65 eligible volunteers consented to take part and were randomized preop-

eratively into 3 groups: aquatic physiotherapy, water exercise, and ward control. Figure 1 details the flow of participants through the trial. Fourteen volunteers were excluded from the RCT at the home visit, 10 because they declined randomization in case they did not receive pool treatment and 4 because they met exclusion criteria. At day 4 after surgery, 11 participants were excluded because of postoperative complications. Three had been admitted to intensive care postoperatively, and 8 experienced complications after surgery such as a fall, urinary tract infection, or postoperative confusion that significantly delayed postoperative recovery. One participant withdrew before discharge from the hospital. Five were lost to follow-up at the day 180 assessment: 1 could not be contacted, 1 was overseas, 1 had undergone bilateral TKRs, 1 had a THR on the opposite side, and 1 had an unrelated medical problem. Where possible, participants were contacted and mailed the questionnaires to complete.

Baseline demographics of the 3 treatment groups were not significantly different (table 1). Average LOS was 1 day less in the aquatic physiotherapy treatment group, but the difference

Table 1: Participant Characteristics Compared With Those Excluded at Day 4

Parameter	Ward (n=17)	Aquatic (n=18)	Water Exercise (n=19)	Between-Group Difference (P)	Excluded Day 4 (n=11)	Between-Group Difference (P)
Age (y)	70.4±9.2	69.4±6.5	69.0±8.9	.87	73.0±9.5	.63
Sex, male, n (%)	5 (29.4)	10 (55.6)	7 (36.8)	.27	8 (72.7)	.10
Height (m)	1.7±0.1	1.7±0.1	1.7±0.1	.84	1.7±0.1	.95
Weight (kg)	79.6±15.1	81.7±18.7	78.5±13.4	.83	78.1±18.3	.92
BMI (kg/cm ²)	28.8±6.2	28.4±4.6	28.0±4.1	.88	27.4±3.9	.89
Joint, THR, n (%)	5 (29.4)	10 (55.6)	12 (63.2)	.10	8 (72.7)	.10
Surgeon, A, n (%)	11 (64.7)	15 (83.3)	13 (68.4)	.43	9 (81.8)	.53
Treatment number	3.3±1.0	3.3±1.1	3.8±1.2	.29	NA	NA
LOS (d)	8.3±1.9	7.4±1.6	8.1±1.7	.29	NA	NA

NOTE. Values are means ± SDs or as otherwise indicated. Abbreviations: BMI, body mass index; NA, not applicable.

between groups was not statistically significant. More participants having a TKR were randomly allocated to the ward treatment group than either the aquatic or the water exercise groups, but again, this was not a significant difference among the groups. No outcome measures were significantly different between treatment groups at preoperative baseline after post hoc analysis with the exception of the average rating of self-efficacy before surgery ($P=.013$). Self-efficacy was therefore used as a covariate in all further analyses.

Of participants who were not excluded at day 4, 27 had a THR and the same number a TKR. Comparing the 9 outcome measures at baseline between those 2 subgroups, only active range of movement ($P=.01$) and circumference ($P=.04$) differed. As would be expected clinically, those undergoing a knee replacement had less active range before surgery, and their circumference was larger, likely a result of the disease process in the joint.

Compliance With Trial Method

All participants except 2 received the protocol in the hospital as allocated. Two participants randomized to the ward-only treatment group received aquatic physiotherapy from day 4, and their data were analyzed as randomized. Throughout the trial, no adverse effects were reported. Early aquatic physiotherapy had been routine in this hospital over many years, and clinical protocols regarding wound management and infection control were well established.

Effect of Intervention

The means $\pm$ SDs of all outcome measures for each treatment group at each time point are presented in table 2. This table displays data as collected and is presented without the last-value-carried-forward data, used to manage missing data. Numbers of participants in each group therefore correspond to the CONSORT diagram (see fig 1). Analysis of the ward group compared with the water exercise group is not presented because it was not an aim of this research study.

Early Postoperative Recovery

Table 3 contains the mean between-group differences and percentage relative differences at day 14, the primary endpoint of the trial.

Primary outcome measures. Hip abductor strength of the aquatic physiotherapy group was significantly greater at day 14 than both the ward treatment group (mean difference=3.9kg, $P=.001$) and the water exercise group (3.1kg, $P=.011$). This was the only primary outcome measure significantly different at that time point. However, the relative differences between the aquatic and ward control groups in table 3 suggest that a clinically important difference may exist in all 3 primary outcome measures of hip abductor strength (31%), 10-m walk time (37%), and WOMAC score (25%) in favor of the aquatic group. Comparing the aquatic and water exercise groups, only hip abductor strength suggests a clinically important difference in the primary outcome measures (17%), again in favor of the aquatic group.

Secondary outcome measures. Adjusting the significance level to compensate for multiple comparisons ($P<.006$), no secondary outcomes were significantly different comparing the aquatic with either the ward or the water exercise groups (see table 3). However, the relative differences in the TUG and PSFS of the aquatic group were greater than 15% compared with either of the other 2 groups, suggesting that a clinically important difference may exist. Although circumference was not significantly different ($P=.032$), 3.7cm less swelling in the

Table 2: Means $\pm$ SDs of All Outcome Measures Collected Throughout the Trial

	Preoperative			Day 14 Postoperative			Day 90 Postoperative			Day 180 Postoperative		
	Ward n=20	Aquatic n=24	Water Exercise n=21	Ward n=17	Aquatic n=17	Water Exercise n=19	Ward n=17	Aquatic n=17	Water Exercise n=19	Ward n=17	Aquatic n=14	Water Exercise n=17
Primary outcome measures												
Hip abductor strength (kg)	8.8 $\pm$ 3.5	10.7 $\pm$ 5.2	7.7 $\pm$ 2.9	5.7 $\pm$ 2.1	10.0 $\pm$ 5.0	5.7 $\pm$ 2.3	11.9 $\pm$ 4.4	14.7 $\pm$ 6.3	10.5 $\pm$ 3.1	15.6 $\pm$ 9.3	16.9 $\pm$ 6.9	13.5 $\pm$ 6.5
10-m walk (s)	14.1 $\pm$ 8.0	10.1 $\pm$ 2.4	13.1 $\pm$ 6.7	20.3 $\pm$ 10.9	15.0 $\pm$ 6.9	17.7 $\pm$ 6.9	10.0 $\pm$ 4.0	8.8 $\pm$ 2.5	9.7 $\pm$ 2.4	10.2 $\pm$ 3.7	8.0 $\pm$ 2.1	9.2 $\pm$ 1.7
WOMAC score (0-96)	48.9 $\pm$ 14.7	51.5 $\pm$ 14.4	53.8 $\pm$ 14.9	46.3 $\pm$ 16.5	37.0 $\pm$ 13.3	34.4 $\pm$ 14.4	21.2 $\pm$ 14.9	18.8 $\pm$ 12.5	20.9 $\pm$ 15.0	14.2 $\pm$ 10.9	13.9 $\pm$ 13.6	14.9 $\pm$ 13.1
Secondary outcome measures												
Quadriceps strength (kg)	10.1 $\pm$ 4.8	14.8 $\pm$ 6.2	11.5 $\pm$ 6.0	8.6 $\pm$ 4.6	12.2 $\pm$ 4.2	9.7 $\pm$ 3.7	13.9 $\pm$ 4.1	17.7 $\pm$ 6.0	14.6 $\pm$ 4.7	17.9 $\pm$ 7.6	19.4 $\pm$ 5.9	16.0 $\pm$ 5.2
Hamstrings strength (kg)	10.6 $\pm$ 5.5	12.9 $\pm$ 4.1	11.2 $\pm$ 4.6	7.3 $\pm$ 4.7	9.6 $\pm$ 4.3	8.1 $\pm$ 2.2	13.1 $\pm$ 5.1	13.3 $\pm$ 5.6	13.1 $\pm$ 4.4	15.3 $\pm$ 7.5	15.5 $\pm$ 5.4	14.0 $\pm$ 5.5
TUG test (s)	15.5 $\pm$ 6.8	12.3 $\pm$ 3.3	16.4 $\pm$ 9.7	25.4 $\pm$ 14.4	18.4 $\pm$ 10.1	19.7 $\pm$ 6.7	11.1 $\pm$ 4.5	9.3 $\pm$ 2.3	10.2 $\pm$ 3.2	10.2 $\pm$ 4.1	8.3 $\pm$ 1.6	9.4 $\pm$ 2.3
Circumference (cm)	42.4 $\pm$ 4.7	41.7 $\pm$ 3.2	41.3 $\pm$ 3.4	46.5 $\pm$ 6.3	42.9 $\pm$ 3.0	43.2 $\pm$ 4.9	44.4 $\pm$ 5.3	42.5 $\pm$ 3.6	42.3 $\pm$ 4.1	43.7 $\pm$ 5.5	41.7 $\pm$ 2.3	42.3 $\pm$ 4.0
ROM knee (degrees)	113.8 $\pm$ 17.2	116.9 $\pm$ 16.5	121.7 $\pm$ 19.0	92.8 $\pm$ 20.3	105.6 $\pm$ 19.9	104.9 $\pm$ 21.9	107.3 $\pm$ 16.1	117.9 $\pm$ 11.5	117.7 $\pm$ 16.0	112.1 $\pm$ 11.9	122.4 $\pm$ 13.5	120.6 $\pm$ 12.1
PSFS (0-10)	3.1 $\pm$ 1.3	3.0 $\pm$ 1.5	2.4 $\pm$ 1.1	2.5 $\pm$ 1.9	3.7 $\pm$ 2.5	2.6 $\pm$ 1.5	6.4 $\pm$ 1.9	7.9 $\pm$ 1.9	6.7 $\pm$ 2.0	8.0 $\pm$ 1.8	8.6 $\pm$ 1.8	8.2 $\pm$ 1.6
Self-efficacy average (0-10)	6.5 $\pm$ 2.4	7.2 $\pm$ 1.8	5.3 $\pm$ 2.2	4.3 $\pm$ 1.8	6.1 $\pm$ 2.2	5.3 $\pm$ 1.9	8.2 $\pm$ 1.7	8.8 $\pm$ 1.5	8.0 $\pm$ 2.0	9.1 $\pm$ 1.2	9.4 $\pm$ 1.1	9.0 $\pm$ 1.4

NOTE: n equals the participant numbers at each assessment time. See figure 1. Abbreviation: ROM, range of motion.

Table 3: Aquatic Intervention Compared to Ward Control and Water Exercise Groups at Day 14

Outcome Measure	Aquatic Physiotherapy Compared to Ward Control			Aquatic Physiotherapy Compared to Water Exercise		
	Mean Difference (95% CI)	Significance (P)	Relative Difference (%) [†]	Mean Difference (95% CI)	Significance (P)	Relative Difference (%) [†]
Primary outcome measures						
Hip abductor strength (kg)	3.9 (1.7 to 6.1)	.001*	31 [†]	3.1 (0.7 to 5.4)	.011	17 [†]
10-m walk (s)	-5.3 (-11.1 to 0.5)	.072	37 [†]	1.0 (-6.8 to 8.8)	.392	14
WOMAC score (0-96)	-7.9 (-17.8 to 2.0)	.115	25 [†]	6.4 (-4.2 to 17.1)	.230	-1.0
Secondary outcome measures						
Quadriceps strength (kg)	3.0 (0.3 to 5.8)	.030	-2	1.1 (-1.8 to 4.0)	.456	8
Hamstrings strength (kg)	1.9 (-0.7 to 4.5)	.139	12	0.6 (-2.2 to 3.4)	.663	5
TUG test (s)	-6.2 (-13.5 to 1.1)	.092	35 [†]	6.4 (-4.2 to 2.5)	.798	19 [†]
Circumference (cm)	-3.7 (-7.1 to -0.3)	.032	5	-0.5 (-4.2 to 3.1)	.764	0.02
ROM knee (degrees)	12.7 (-1.6 to 27.0)	.081	9	-2.7 (-8.9 to 3.5)	.948	3
PSFS (0-10)	1.2 (-0.2 to 2.5)	.088	41 [†]	1.1 (-0.4 to 2.5)	.145	25 [†]

Abbreviation: ROM, range of motion.

*Significance for primary outcomes $P < .05$, secondary outcomes $P < .006$ (Bonferroni correction).

[†]Relative difference: a value greater than 15% indicates a clinically important difference between the intervention and control groups.

aquatic compared with the ward groups (95% CI, -7.1 to -0.3) could be clinically important. The relative difference in circumference was unlikely to be greater than 15% because the mean change from baseline (2.3cm) was divided by the average circumference (42cm).

Longer-Term Recovery

Table 4 contains the comparison between the 3 groups at day 90 and day 180. Relative differences were not calculated for these later assessment points because participants were free to undertake whatever, if any, rehabilitation they chose after day 14 assessments, and therefore intervention was not controlled as it had been for the inpatient component of the research.

Primary outcome measures. A mean difference in abductor strength between the aquatic and ward groups was not evident at day 90. However, there was a trend for the water exercise group to remain significantly weaker in hip abduction than the aquatic group (3.4kg; $P = .054$). This difference was no longer evident at day 180. No other primary outcome measures were statistically significant at either time point.

Secondary outcome measures. As shown in table 4, after adjusting for multiple comparisons, there were no significant differences between the aquatic physiotherapy and water exercise groups in secondary outcome measures at day 90 or day 180. There were trends for greater quadriceps strength at day 90

($P = .037$) and knee range at both day 90 ($P = .049$) and day 180 ($P = .014$) in the aquatic group than the ward control.

Early Recovery After Total Hip Replacement or Total Knee Replacement Surgery

The data were then examined separately for subjects undergoing a TKR (table 5) or a THR (table 6). No significant differences in baseline measures were demonstrated after post hoc analysis. Hip abductor strength had improved more in those having aquatic physiotherapy after TKR than in those in either the ward control group (mean difference = 6.6kg; $P = .000$) or the water exercise group (4.3kg; $P = .025$). Differences in hip abductor strength after THR were not significant among the 3 groups, although there was a trend ($P = .055$) for the aquatic group to show greater strength than the ward control. Of the secondary strength measures in those with TKR (see table 5), quadriceps strength of the aquatic group was significantly greater than the ward group ($P = .005$), with a trend to be stronger than the water exercise group also ($P = .046$). There were no significant differences with any other measures after THR (see table 6).

DISCUSSION

No studies to our knowledge have been published investigating the use of aquatic physiotherapy from day 4 postoper-

Table 4: Aquatic Intervention Compared to Ward Control and Water Exercise Groups at Day 90 and 180

Outcome Measure	Day 90				Day 180			
	Aquatic and Ward Control		Aquatic and Water Exercise		Aquatic and Ward Control		Aquatic and Water Exercise	
	Mean Difference (95% CI)	Significance (P)	Mean Difference (95% CI)	Significance (P)	Mean Difference (95% CI)	Significance (P)	Mean Difference (95% CI)	Significance (P)
Primary outcome measures								
Hip abductor strength (kg)	2.5 (-0.8 to 5.7)	.132	3.4 (-0.1 to 6.8)	.054*	-0.1 (-5.2 to 5.0)	.971	1.2 (-4.3 to 6.7)	.657
10-m walk (s)	-0.8 (-2.9 to 1.2)	.412	-0.0 (-2.2 to 2.1)	.978	-1.6 (-3.5 to 0.9)	.102	-0.5 (-2.6 to 1.5)	.607
WOMAC score (0-96)	-0.9 (-10.4 to 8.6)	.849	2.0 (-8.1 to 12.2)	.691	-0.4 (-8.5 to 7.7)	.929	0.7 (-8.0 to 9.4)	.872
Secondary outcome measures								
Quadriceps strength (kg)	3.6 (0.2 to 7.1)	.037	2.7 (-1.0 to 6.3)	.151	0.4 (-3.9 to 4.8)	.837	1.9 (-2.8 to 6.5)	.425
Hamstrings strength (kg)	0.2 (-3.2 to 3.7)	.897	0.2 (-3.5 to 4.0)	.904	-0.1 (-4.4 to 4.2)	.952	0.9 (-3.7 to 5.6)	.682
TUG test (s)	-1.4 (-3.6 to 0.9)	.228	0.5 (-1.9 to 2.8)	.704	-1.2 (-3.3 to 0.9)	.260	-0.3 (-2.6 to 2.0)	.789
Circumference (cm)	-2.1 (-5.1 to 0.9)	.171	-0.3 (-3.6 to 2.9)	.833	-2.3 (-5.2 to 0.7)	.127	0.7 (-2.3 to 3.7)	.329
ROM knee (degrees)	10.2 (0.1 to 20.3)	.049	-1.0 (-11.9 to 9.8)	.848	10.7 (2.2 to 19.2)	.014	1.9 (-7.2 to 11.0)	.676
PSFS (0-10)	1.4 (0.1 to 2.8)	.088	1.0 (-0.4 to 2.5)	.151	0.5 (-0.7 to 1.7)	.427	0.2 (-1.0 to 1.5)	.720

Abbreviation: ROM, range of motion.

*Significance for primary outcomes $P < .05$, secondary outcomes $P < .006$ (Bonferroni correction).

Table 5: Comparison Between Baseline and Day 14: Total Knee Replacement

Outcome Measures	Preoperative				Day 14 Postoperative			Day 14 Between-Group Mean Difference			
	Ward n=12	Aquatic n=8	Water Exercise n=7	Between-Group Difference (<i>P</i>)	Ward n=12	Aquatic n=8	Water Exercise n=7	Aquatic and Ward Control		Aquatic and Water Exercise	
								95% CI	<i>(P)</i>	95% CI	<i>(P)</i>
Primary outcome measures											
Hip abductor strength (kg)	9.0±1.2	12.9±1.5	9.2±1.6	.022*	6.0±0.9	12.6±1.1	8.3±1.2	6.6 (3.6 to 9.5)	.000 [†]	4.3 (0.6 to 8.0)	.025
10-m walk (s)	12.3±1.4	12.2±1.8	11.7±1.9	.318	21.1±2.7	16.8±3.5	17.0±3.8	−4.3 (−13.4 to 4.8)	.343	−0.2 (−11.6 to 11.2)	.970
WOMAC score (0–96)	48.5±4.3	50.7±5.6	51.4±6.1	.378	48.4±5.0	37.1±6.6	32.4±7.1	−11.2 (−28.3 to 5.9)	.188	4.7 (−16.6 to 26.1)	.650
Secondary strength measures											
Quadriceps strength (kg)	9.7±1.4	14.5±1.8	10.5±2.0	.029*	7.3±0.8	11.1±1.0	7.9±1.1	3.9 (1.3 to 6.4)	.005 [†]	3.2 (0.6 to 6.4)	.046
Hamstrings strength (kg)	9.3±1.1	11.3±1.4	11.0±1.5	.293	5.3±0.7	6.8±1.0	7.1±1.1	1.5 (−1.0 to 4.0)	.240	−0.4 (−3.5 to 2.8)	.817

NOTE: Values are group means ± SEs or as otherwise indicated.

*Between-group difference not significant after post hoc analysis: hip abduction strength, aquatic and ward $P=.183$, aquatic and water exercises $P=.130$; quads, aquatic and ward $P=.166$, aquatic and water exercise $P=.088$.

[†]Significance for primary outcomes $P<.05$, secondary outcomes $P<.006$ (Bonferroni correction).

actively after THR or TKR surgery. This RCT was therefore undertaken in a clinical setting to investigate whether inpatient aquatic physiotherapy from day 4 in addition to usual ward physiotherapy improved early functional recovery more than nonspecific water exercise or additional ward physiotherapy. By day 14 after surgery, those in the aquatic physiotherapy group had significantly greater hip abductor strength than those who received additional ward treatment or water exercise. No other primary or secondary outcome measures were significantly different between the 3 groups at day 14, although relative differences favored the aquatic group. Hip abductor strength was the only outcome measure to appear different in the longer term, with a trend for the water exercise group still to be not as strong as the aquatic group at day 90.

Hip abductor strength is an important component of mediolateral stability⁶⁶ and functional activities such as walking and stepping,⁶⁷ but this strength is reduced in people with hip OA^{35,36} and with increasing age.³³ Decreased quadriceps strength has also been associated with falls risk and reduced mediolateral stability³¹ and is decreased in people with OA⁶⁸ and after joint replacement surgery.^{24,28} Improving muscle strength, gaining range, and re-educating gait are the focus of physiotherapy programs after joint replacement surgery,¹¹ but in contrast with quadriceps strength, hip abductor strength has rarely been studied either in people with OA or after joint replacement.³ Early water exercise has been recommended in clinical guidelines for rehabilitation after hip arthroscopy procedures,¹⁰ but few details of the specific aquatic activities were included, and it is not clear whether the exercise was undertaken independently or with supervision. A specific aquatic physiotherapy program has previously been shown to improve hip abductor strength in people with osteoarthritis.⁶⁹ This pro-

gram was similar to our study, and both included exercises for each limb. Participants in the aquatic intervention group of our study stood on the operated limb and had to maintain stability while moving the opposite limb at the specified metronome pace. This exercise is likely to have enhanced hip abductor strength because of the need to control mediolateral stability. In contrast, other researchers²⁹ found that a gym program improved quadriceps strength in people with OA more than a hydrotherapy program. Their hydrotherapy program was not specifically described but did not appear to include functional strengthening and was focused on speed in the pool to maintain exercise heart rate, which is likely to be why the aerobic fitness of hydrotherapy participants improved but not their strength. Our results indicate that further research is needed to examine the role of the hip abductor strength in function and mobility after THR and TKR.

Despite the obvious differences between THR and TKR surgery, the rate of postoperative recovery has been found to be similar.⁷⁰ In one study that, like ours, included subjects with both THR and TKR, variance in early functional recovery of 6-minute walk test distance and TUG was explained more by preoperative baseline score than the site of arthroplasty, and changes in WOMAC pain subscale beyond 1 week postoperatively followed a similar pattern after both THR and TKR surgery.⁷¹ Participants in our study with either THR or TKR also had comparable patterns of impairments and disability at baseline. Because similar patterns of muscle dysfunction are present in knee and hip OA, published guidelines for inpatient physiotherapy intervention programs to regain strength and function after THR or TKR are very similar.¹¹ Likewise, studies of aquatic physiotherapy intervention for people with OA of the hip and knee have included subjects with either condition in

Table 6: Comparison Between Baseline and Day 14: Total Hip Replacement

Outcome Measures	Preoperative				Day 14 Postoperative			Day 14 Between-Group Mean Difference			
	Ward n=5	Aquatic n=10	Water Exercise n=12	Between-Group Difference (<i>P</i>)	Ward n=5	Aquatic n=10	Water Exercise n=12	Aquatic Compared to Ward		Aquatic Compared to Water Exercise	
								95% CI	<i>(P)</i>	95% CI	<i>(P)</i>
Primary outcome measures											
Hip abductor strength (kg)	9.5±1.6	7.9±1.2	7.9±1.1	.514	4.5±1.0	7.1±0.8	5.1±0.7	2.6 (−0.0 to 5.2)	.055	2.0 (−0.2 to 4.3)	.073
10-m walk (s)	10.2±1.7	9.6±1.3	12.2±1.2	.386	18.2±3.5	13.6±2.6	18.2±2.4	−4.6 (−13.4 to 4.2)	.292	−4.6 (−12.2 to 2.9)	.219
WOMAC score (0–96)	50.8±4.8	57.2±3.6	45.4±3.3	.824	42.1±5.2	40.0±3.9	32.6±3.6	−2.1 (−15.3 to 11.2)	.749	7.4 (−4.0 to 18.8)	.193
Secondary strength measures											
Quadriceps strength (kg)	13.3±2.5	13.5±1.8	12.5±1.7	.711	11.5±2.0	11.8±1.5	11.9±1.4	0.3 (−4.8 to 5.5)	.890	−0.1 (−4.6 to 4.3)	.953
Hamstrings strength (kg)	15.6±2.1	11.9±1.6	12.0±1.4	.198	11.9±1.6	11.0±1.1	9.5±1.1	−1.0 (−4.9 to 2.9)	.611	1.4 (−1.9 to 4.8)	.392

NOTE: Values are group means ± SEs unless otherwise indicated.

*Significance for primary outcomes $P<.05$, secondary outcomes $P<.006$ (Bonferroni correction).

the same study and used the same exercise protocol for both.^{29,69,72} The significant improvement in hip abductor strength found in our study was surprising considering that more than half the participants in the aquatic group had a THR involving a posterior-lateral surgical approach, compared with less than a third of participants in the ward treatment group. Similarities in other outcome measures showed that inpatient aquatic physiotherapy was as effective as additional ward treatment in improving range, walking speed, and self-reported function. Little research has been undertaken on inpatient physiotherapy intervention, with the exception of continuous passive motion.^{73,74} Even a recent systematic review of functional physiotherapy exercise for TKR after discharge included only 6 trials of mostly low-intensity exercise,⁷ so their positive conclusions should be interpreted cautiously.⁷⁵ Further research is clearly needed to inform clinical practice.

A recent Cochrane Review⁷⁶ concluded that aquatic exercise was likely to improve pain and function in people with hip or knee OA, but the type and amount of aquatic exercise that was most beneficial was not clear, particularly with regard to hip OA. Group aquatic physiotherapy was not used in our study in order to standardize the interventions and to monitor the physiologic effects of immersion on each individual in the early postoperative days. In our study, hip abductor strength improved more in the aquatic physiotherapy group than the non-specific water exercise program, but there was no difference in the other outcome measures assessed. The effect of hydrostatic pressure when immersed to 1.2m is greater than diastolic blood pressure,¹⁶ and this graduated increase in pressure with increasing water depth, similar to a compression garment, is thought to aid in the resolution of edema. The addition of exercise while immersed has been shown to improve dependent edema in pregnant women¹⁴ and lower-limb lymphoedema.¹⁵ It was not unexpected that swelling measured by knee circumference did not differ between the 2 pool groups, but the difference between the aquatic and ward exercise group was -3.7cm (95% CI, -7.1 to -0.3). Clearer results may have been obtained had a series of circumferential measurements above and below the knee been used rather than a single measurement around the knee joint itself. Participants in our trial attended an average of only 3.5 treatments before discharge. More treatments over a longer period might have been needed to detect greater differences between the 2 water-based programs. No adverse events occurred with any of the participants who came into the pool early after joint replacement surgery.

Study Limitations

Results of this trial must be interpreted with caution for several reasons. Rates of recovery after hip and knee replacement surgery may vary, particularly in the early postoperative period, but few studies have been published on which to

determine whether this is actually the case. The greatest number of participants excluded at day 4 were from the aquatic physiotherapy intervention, so despite there being no significant difference between the groups at baseline, the aquatic group may well have been different because of factors related to early postoperative recovery rather than the specific intervention. However, this postoperative variability is likely to be one of the reasons that few studies of physiotherapy intervention in the early postoperative phase have been undertaken. Given this variability, the small sample size may have masked the true effect of the interventions. In addition, combining participants with THR and TKR within the 1 trial may have influenced the clarity of the results despite there being no significant preoperative differences between the 2 surgical groups. More importantly, multiple comparisons between small numbers of participants mean that the possibility of a type II error cannot be ignored. Future studies of early treatment options are indicated and may be more robust if larger numbers of participants are recruited, or people undergoing hip or knee replacement surgery are investigated separately.

CONCLUSIONS

This is the first study to our knowledge investigating additional aquatic physiotherapy from day 4 after THR or TKR. Methodologic issues limit firm conclusions, but it is likely that a specific aquatic physiotherapy intervention had a beneficial effect on the recovery of hip muscle strength early after surgery. No other outcome measures were significantly different between the groups, although there was a trend for results to favor the aquatic intervention. No adverse events occurred in either of the groups who came to the pool early after THR or TKR surgery, indicating that aquatic physiotherapy is a safe and effective alternative to additional ward physiotherapy. Because this study was undertaken within a private hospital under usual clinical conditions, results cannot necessarily be generalized to other settings such as public hospitals, where waiting time prior to surgery is often much longer and therefore preoperative disability may be even greater. Further studies are required to confirm our findings and to determine whether this improved postoperative strength translates into better medio-lateral stability, and therefore greater improvements in gait pattern and other functional activities such as stepping.

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APPENDIX 1: DETAILS OF PHYSIOTHERAPY PROGRAMS

Ward Exercise Program (As Per Hospital's Clinical Pathway)	Aquatic Physiotherapy Program (Fast Pace=Metronome 80–88bpm)	Water Exercise Program (Slow Pace=Metronome 50–58bpm)
Exercises for both TKR and THR unless indicated otherwise <u>Bed exercises</u> × 10 each Inner range quads Active hip and knee flexion Bridging	Xiphisternal level (30% WB) Progressed to waist deep (50% WB as pain allows) Walk forward, backward, and sideways 2–6 widths, focus on gait pattern and trunk stability	Neck-deep water (10% WB) Walk forwards 5 minutes Posture correction with no other cues (just asked to practice standing tall) 2–3min Single leg balance on nonoperated leg 10–15s, × 10–20 reps

APPENDIX 1: DETAILS OF PHYSIOTHERAPY PROGRAMS (cont'd)

Ward Exercise Program (as per hospital's clinical pathway)	Aquatic Physiotherapy Program (fast pace=metronome 80–88bpm)	Water Exercise Program (slow pace=metronome 50–58bpm)
Circulation exercises: static gluts/quads/ankle dorsiflexion and plantarflexion $\times$ 20 Deep breathing exercises Straight leg raise (TKR) Active hip abduction (THR) <u>Seated in chair or side of bed</u> Active knee flexion (TKR) <u>Transfer practice</u> In/out of bed and in/out of chair <u>Gait re-education</u> With appropriate walking aid and also in parallel bars using a mirror: aim is discharge on elbow crutches <u>Standing exercises</u> at bedside or in gym $\times$ 10 Hip abduction (stand on nonoperated leg, THR) Hip flex/ext (stand on nonoperated leg) Hip and knee flexion (marching) Mini-squats Calf stretch Up on toes Hamstrings curl (knee flex in hip extension) <u>Stair practice</u> Aim is day 5 but dependent on mobility status	Hip abd and add (in 15° hip ext) Hip flex/ext focus on getting into ext Both fast pace and $\times$ 10, progress to 30 per leg Mini-squat slow and controlled (count 1-2-3 then up) $\times$ 10–30 Alternate heel raises (walk on spot) $\times$ 10–30 Day 5/6 added step-ups $\times$ 10–30 Lunge: TKR onto step, THR on pool floor Slowly, $\times$ 10 each leg <u>In pool corner or on plinth</u> Focus on control of pelvic stability during exercises Scissors (no floats) fast pace, 2–3min Hip extension with knee ext and float on ankle, alternating left then right leg (1–2 rings) slow count 1-2-3 down and up; $\times$ 10–30 each leg Backstroke kick and cycle legs fast pace, 2–3min each, flippers by day 5–6 if pain allows <u>Sit on plinth or chair (monitor hip flex ROM)</u> Alternate knee flex/ext $\times$ 2 minutes, TKR + ankle weight day 5–6 <u>Standing xiphisternal level (30% WB)</u> 1–3 minutes, fast pace with focus on trunk stability and even weight-bearing Double arm swing (bilateral UL flex/ext with elbow ext) Alternate arm swing (1 arm forward while 1 arm goes back)	March on spot slow pace, $\times$ 10 and progress to 40 reps <u>In pool corner or on plinth</u> 3–5min each Scissors (bilateral hip abduction and adduction) with floats on each ankle, slow pace Cycle legs, slow pace Active knee flex/ext over a float slow pace <u>Supine float using neck, hip and knee floats</u> 10min Lateral trunk flexion-relaxation Bilateral sculling with arms Gentle, nonspecific lumbar spine mobilizations <u>Standing neck deep water (10% WB)</u> 2–3min each Clapping hands (shoulder int and ext rotation with elbows at sides) slow pace Elbow flexion and extension slow pace Additional forward walking In deep water (10%) WB as above if needed to make time up to 40min

NOTE. Each program was a maximum of 40 minutes.

Abbreviations: abd, abduction; add, adduction; bpm, beats per minute; ext, extension; flex, flexion; int, internal; ROM, range of motion; UL, upper limb; WB, weight-bearing.

References

- Juhakoski R, Tenhonen S, Anttonen T, Kauppinen T, Arokoski JP. Factors affecting self-reported pain and physical function in patients with hip osteoarthritis. *Arch Phys Med Rehabil* 2008;89:1066-73.
- Stratford PW, Kennedy DM, Woodhouse LJ. Performance measures provide assessments of pain and function in people with advanced osteoarthritis of the hip or knee. *Phys Ther* 2006;86:1489-96.
- Bennell KL, Hunt MA, Wrigley TW, Hunter DJ, Hinman RS. The effects of hip muscle strengthening on knee load, pain and function in people with knee osteoarthritis: a protocol for a randomised, single-blinded controlled trial. *BMC Musculoskelet Disord* 2007;8:121-7.
- AON. Australian Orthopaedic Association National Joint Replacement Registry Annual Report. Adelaide: AON; 2007.
- Rooks DS, Huang J, Bierbaum BE, et al. Effect of pre-operative exercise on measures of functional status in men and women undergoing total hip and knee arthroplasty. *Arthritis Rheum* 2006;55:700-8.
- Kim S, Losina E, Solomon DH, Wright J, Katz JN. Effectiveness of clinical pathways for total knee and hip arthroplasty. *J Arthroplasty* 2003;18:69-74.
- Minns Lowe CJ, Barker KL, Dewey M, Sackley CM. Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. *BMJ* 2007;335:812.
- Enloe LJ, Shields RK, Smith K, Leo K, Miller B. Total hip and knee replacement treatment programs: a report using consensus. *J Orthop Sports Phys Ther* 1996;23:3-11.
- Naylor J, Harmer A, Fransen M, Crosbie J, Innes L. Status of physiotherapy rehabilitation after total knee replacement in Australia. *Physiother Res Int* 2006;11:35-47.
- Stalzer S, Wahoff M, Scanlan M. Rehabilitation following hip arthroscopy. *Clin Sports Med* 2006;25:337-57.
- Chipchase LS, Brumby SA. In-patient physiotherapy: management of orthopaedic surgery. Oxford: Butterworth-Heinemann; 2001.
- Denis M, Moffet H, Caron F, Ouellet D, Paquet J, Nolet L. Effectiveness of continuous passive motion and conventional physical therapy after total knee arthroplasty: a randomised clinical trial. *Phys Ther* 2006;86:174-85.
- Shelbourne KD. Invited commentary. *J Orthop Sports Phys Ther* 2005;35:61-2.
- Hartmann S, Huch R. Response of pregnancy leg edema to a single immersion exercise session. *Acta Obstetr Gynecol Scand* 2005;84:1150-3.

15. Tidhar D, Drouin J, Shimony A. Aqua lymphatic therapy in managing lower extremity lymphedema. *J Support Oncol* 2007;5: 179-83.
16. Becker BE. Biophysiological aspects of hydrotherapy. In: Cole AJ, Becker BE, editors. *Comprehensive aquatic therapy*. Philadelphia: Butterworth Heinemann; 2004.
17. Harrison RA, Hillman M, Bulstrode S. Loading of the lower limb when walking partially immersed: implications for clinical practice. *Physiotherapy* 1992;78:164-6.
18. Sherrington C, Lord S, Herbert R. A randomised trial of weight-bearing versus non-weight-bearing exercise for improving physical ability in inpatients after hip fracture. *Aust J Physiother* 2003;49:15-22.
19. Olivetti L, Schurr K, Sherrington C, et al. A novel weight-bearing strengthening program during rehabilitation of older people is feasible and improves standing up more than a non-weight-bearing strengthening program: a randomised trial. *Aust J Physiother* 2007;53:417-53.
20. Moffet H, Collet JP, Shapiro S, Paradis G, Marquis F, Roy L. Effectiveness of intensive rehabilitation on functional ability and quality of life after first total knee arthroplasty: a single-blind randomised controlled trial. *Arch Phys Med Rehabil* 2004;85: 546-56.
21. Brandt KD. Putting some muscle into osteoarthritis. *Ann Int Med* 1997;127:138-41.
22. Sims K. The development of hip osteoarthritis: implications for conservative management. *Man Ther* 1999;4:127-35.
23. Hurley MV. Muscle dysfunction and effective rehabilitation of knee osteoarthritis: what we know and what we need to find out. *Arthritis Rheum* 2003;49:444-52.
24. Reardon K, Galea M, Dennett X, Choong P, Byrne E. Quadriceps muscle wasting persists 5 months after total hip arthroplasty for osteoarthritis of the hip: a pilot study. *Int Med J* 2001;31:7-14.
25. Stevens JE, Mizner RL, Snyder-Mackler L. Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis. *J Orthop Res* 2003;21:775-9.
26. Rossi MD, Brown LE, Whitehurst MA. Assessment of hip extensor and flexor strength two months after unilateral total hip arthroplasty. *J Strength Cond Res* 2006;20:262-7.
27. van der Linden M, Rowe P, Myles C, Burnett R, Nutton R. Knee kinematics in functional activities seven years after total knee arthroplasty. *Clin Biomech (Bristol, Avon)* 2007;22:537-42.
28. Yoshida Y, Mizner RL, Ramsey DK, Snyder-Mackler L. Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time. *Clin Biomech (Bristol, Avon)* 2008;23:320-8.
29. Foley A, Halbert J, Hewitt T, Crotty M. Does hydrotherapy improve strength and physical function in patients with osteoarthritis—a randomised controlled trial comparing a gym based and a hydrotherapy strengthening programme. *Ann Rheum Dis* 2003; 62:1162-7.
30. Maly MA, Cosigtan PA, Olney SJ. Determinants of self-report outcome measures in people with knee osteoarthritis. *Arch Phys Med Rehabil* 2006;87:96-104.
31. Lord S, Rogers MW, Howland A, Fitzpatrick R. Lateral stability, sensori-motor function and falls in older people. *J Am Geriatr Soc* 1999;47:1077-81.
32. Hilliard MJ, Martinez KM, Janssen I, et al. Lateral balance factors predict future falls in community-living older adults. *Arch Phys Med Rehabil* 2008;89:1708-13.
33. Johnson ME, Mille M-L, Martinez K, Crombie G, Rogers MW. Age-related changes in hip abductor and adductor joint torques. *Arch Phys Med Rehabil* 2004;85:593-7.
34. Low Choy NL, Brauer S, Nitz JC. Age-related changes in strength and somatosensation during midlife. *Ann N Y Acad Sci* 2007; 1114:180-93.
35. Sims KJ, Richardson CA, Brauer SG. Investigation of hip abductor activation in subjects with clinical unilateral hip osteoarthritis. *Ann Rheum Dis* 2002;61:687-92.
36. Amaro A, Amando F, Duarte JA, Appell H-J. Gluteus medius muscle atrophy is related to contralateral and ipsilateral hip joint osteoarthritis. *Int J Sports Med* 2007;28:1035-9.
37. Ireland LM, Wilson JD, Ballantyne BT, Davis IM. Hip strength in females with and without patellofemoral pain. *J Orthop Sports Phys Ther* 2003;33:671-6.
38. Tyler TF, Nicholas SJ, Mullaney MJ, McHugh MP. The role of hip muscle function in the treatment of patello-femoral pain syndrome. *Am J Sports Med* 2006;34:630-6.
39. Jaramillo J, Worrell T, Ingersoll C. Hip isometric strength following knee surgery. *J Orthop Sports Phys Ther* 1994;20:160-5.
40. Bullock-Saxton JE. Local sensation changes and altered hip muscle function following severe ankle sprain. *Phys Ther* 1994;74: 17-31.
41. Friel K, McLean N, Myers C, Caceres M. Ipsilateral hip abductor weakness after inversion ankle sprain. *J Athl Train* 2006;41:74-8.
42. Poyhonen T, Keskinen K, Hautala A, Malkia E. Determination of hydrodynamic drag forces and drag coefficients on human leg/foot model during knee exercises. *Clin Biomech (Bristol, Avon)* 2000; 15:256-60.
43. Bellamy N, Kirwan J, Boers M, et al. Recommendations for a core set of outcome measures for future phase III clinical trials in knee, hip and hand osteoarthritis: consensus development at OMERACT III. *J Rheum* 1997;24:799-802.
44. Andrews AW, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometer. *Phys Ther* 1996;76:248-59.
45. Sherrington C, Lord S. Reliability of simple portable tests of physical performance in older people after hip fracture. *Clin Rehabil* 2005;19:496-504.
46. Schaubert KL, Bohannon RW. Reliability and validity of three strength measures obtained from community-dwelling elderly persons. *J Strength Cond Res* 2005;19:717-20.
47. Kwok CK, Petrick MA, Munin MC. Inter-rater reliability for function and strength measurements in the acute care hospital after elective hip and knee arthroplasty. *Arthritis Care Res* 1997;10: 128-34.
48. Sherrington C, Lord S, Herbert R. A randomised controlled trial of weight-bearing versus non-weight-bearing exercise for improving physical ability after usual care for hip fracture. *Arch Phys Med Rehabil* 2004;85:710-6.
49. Pua YH, Wrigley TW, Cowan SM, Bennell KL. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. *Arch Phys Med Rehabil* 2008;89:1146-54.
50. Wang CY, Olson S, Protas E. Test-retest strength reliability: hand-held dynamometry in community-dwelling elderly fallers. *Arch Phys Med Rehabil* 2002;83:811-5.
51. Bohannon RW, Andrews AW, Thomas MW. Walking speed: reference values and correlates for older adults. *J Orthop Sports Phys Ther* 1996;24:86-90.
52. Fransen M, Crosbie J, Edmunds J. Reliability of gait measurements in people with osteoarthritis of the knee. *Phys Ther* 1997; 77:944-53.
53. Stratford PW, Kennedy DM, Pagura SM, Gollish JD. The relationship between self-report and performance-related measures: questioning the content validity of timed tests. *Arthritis Rheum* 2003;49:535-40.
54. Wade DT, Wood VA, Heller A, Maggs J, Langton Hewer R. Walking after stroke. Measurement and recovery over the first 3 months. *Scand J Rehabil Med* 1987;19:25-30.

55. Börjesson M, Robertson E, Weidenhielm L, Mattsson E, Olsson E. Physiotherapy in knee osteoarthritis: effect on pain and walking. *Physiother Res Int* 1996;1:89-97.
56. Graham JE, Ostir GV, Kuo YF, Fisher SR, Ottenbacher KJ. Relationship between test methodology and mean velocity in timed walk tests: a review. *Arch Phys Med Rehabil* 2008;89: 865-72.
57. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to anti-rheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988;15:1833-40.
58. Fortin P, Clarke A, Joseph L, et al. Outcomes of total hip and knee replacement. *Arthritis Rheum* 1999;42:1722-8.
59. Jones CA, Voaklander DC, Suarez-Almazor ME. Determinants of function after total knee arthroplasty. *Phys Ther* 2003;83:696-706.
60. Taylor R, Jayasinghe UW, Koelmeyer L, Ung O, Boyages J. Reliability and validity of arm volume measurements for assessment of lymphedema. *Phys Ther* 2006;26:205-14.
61. Podsiadlo D, Richardson S. The Timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;39:142-8.
62. Lorig K, Stewart A, Ritter P, Gonzalez V, Laurent D, Lynch J. Outcome measures for health education and other health care interventions. London: Sage Publications; 1996.
63. Stratford P, Gill C, Westaway M, Binkley JM. Assessing disability and change of individual patients: a report of a patient specific measure. *Physiother Can* 1995;47:258-63.
64. Chatman AB, Hyams SP, Neel JM, et al. The Patient-Specific Functional Scale: measurement properties in patients with knee dysfunction. *Phys Ther* 1997;77:820-9.
65. Albright J, Allman R, Bonfiglio R, et al. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions: overview and methodology. *Phys Ther* 2001; 81:1629-40.
66. Nitz JC, Low Choy NL, Isles RC. Medial-lateral postural stability in community-dwelling women over 40 years of age. *Clin Rehabil* 2003;17:765-7.
67. Sims K, Brauer S. A rapid upward step challenges medio-lateral postural stability. *Gait Posture* 2000;12:217-24.
68. Slemenda C, Brandt K, Heilman D, et al. Quadriceps weakness and osteoarthritis of the knee. *Ann Int Med* 1997;127:97-104.
69. Hinman RS, Heywood SE, Day AR. Aquatic physiotherapy for hip and knee osteoarthritis: results of a single-blind randomised controlled trial. *Phys Ther* 2007;87:32-43.
70. Ackerman IN, Graves SE, Bennell KL, Osborne RH. Evaluating quality of life in hip and knee replacement: psychometric properties of the World Health Organisation Quality of Life Short Version Instrument. *Arthritis Rheum* 2006;55:583-90.
71. Kennedy DM, Stratford PW, Hanna SE, Wessel J, Gollish JD. Modeling early recovery of physical function following hip and knee arthroplasty. *BMC Musculoskelet Disord* 2006;7:100-13.
72. Alexander MJ, Butcher JE, MacDonald PB. Effect of a water exercise program on walking gait, flexibility, strength, self-reported disability and other psycho-social measures of older individuals with arthritis. *Physiother Can* 2001;53:203-11.
73. Bennett LA, Brearley SC, Hart JA, Bailey MJ. A comparison of 2 continuous passive motion protocols after total knee arthroplasty. *J Arthroplasty* 2005;20:225-33.
74. Beaupre L, Davies D, Jones C, Cinats J. Exercise combined with continuous passive motion or slider board therapy compared with exercise only: a randomised controlled trial of patients following total knee arthroplasty. *Phys Ther* 2001;81:1029-37.
75. Herbert R, Fransen M. Management of chronic knee pain. *BMJ* 2007;335:786.
76. Bartels EM, Lund H, Hagen KB, Dagfinrud H, Christensen R, Danneskiold-Samsøe B. Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database Syst Rev* 2007; (4):CD005523.

Suppliers

- a. Occlusive waterproof dressing, Op-Site post-op; Smith + Nephew Medical Pty Ltd, 315 Ferntree Gully Rd, Mt Waverley, Victoria, 3149 Australia.
- b. Hand-held dynamometer, Lafayette Model 01163; Lafayette Instrument Co, PO Box 5729, Lafayette, IN 47903.
- c. SPSS for Windows, version 13; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.